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Architecture-based Operations Analysis

An Extension of Classical Operations Analysis

Dickerson, Brady, Canterbury, Cordell, Fortunato, Peppers, et al

C.E. Dickerson, Technical Fellow

Presented to the 73rd MORS Symposium

21 – 23 June 2005

charles.dickerson@baesystems.com

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Purpose

- **Establish key concepts**
- **Introduce a proposed definition**
- **Give one simple quantitative example**
  - **Based on GIG Block 4 Scenario, NCOW Reference Model and UJTL**
  - **Suitable for tools like Telelogic System Architect, OPNET, EADSIM**
  - **Illustrating the key concepts and proposed definition**

The need for an architecture-based approach to operations analysis has arisen from architecture-based systems engineering, which seeks to engineer systems at the system of systems and family of systems level.*

***Using Architectures for Research, Development, and Acquisition by Dickerson, Soules, Sabins, and Charles**
Available via DTIC: (www.dtic.mil) *AD Number* ADA427961

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Definition of Terms

- ***Architecture* is***

  the structure of components, their relationships, and the principles and guidelines governing their design and evolution over time.

- ***Integrated Architecture***

  has products whose constituent architecture data elements are such that the architecture data elements defined in one view are the same (i.e. the same names, definitions, and values) as the architecture data elements referenced in another.

- ***Operations Analysis* is****

  "the application of scientific principles and quantitative methods in the analysis of complex real-world systems; to include the study of military problems undertaken to provide responsible commanders and staff agencies with *a sound scientific basis for decision on actions to improve military operations*"

- **A *capability****

  is the ability to execute a specified course of action [sequence of activities].

**IEEE STD 610.12. In this briefing, the DoDAF 1.0 will be used as the DoD standard for architectures.*
***Composite definition JP 1-02 and assorted government sources*
****JP 1-02, DoD Dictionary of Terms*

Relation of Architecture to Operations

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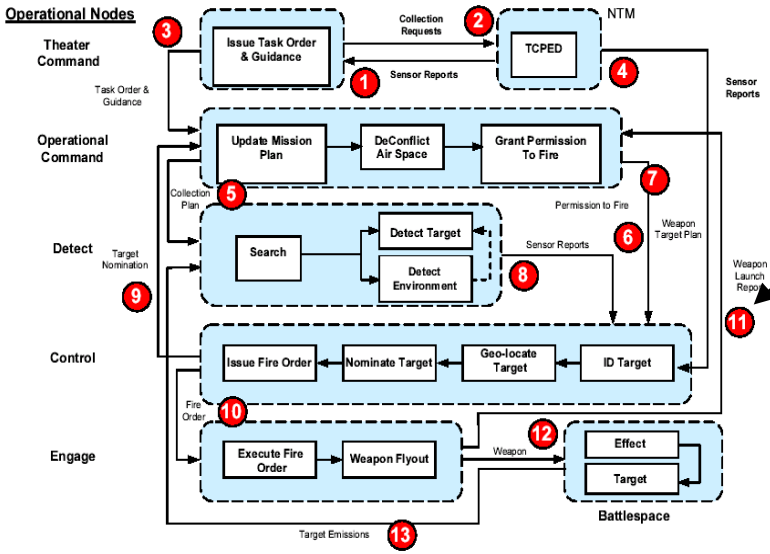
Architectural Model of an Operational Capability



- **The DoDAF OV-6c gives an architectural model of capability**
  - **Integration of OV-6c with OV-2 highlights interoperability**
  - **Dependencies of capabilities on interoperability become traceable**
- **Operational nodes (OV-2) aggregate operational activities.**
- **Systems nodes (SV-1) aggregate systems functionality.**
- **The OV-6c supports concordance between M&S of capabilities and the assessment of interoperability.**

Interoperability exists at the nodal level and enables operational capabilities.

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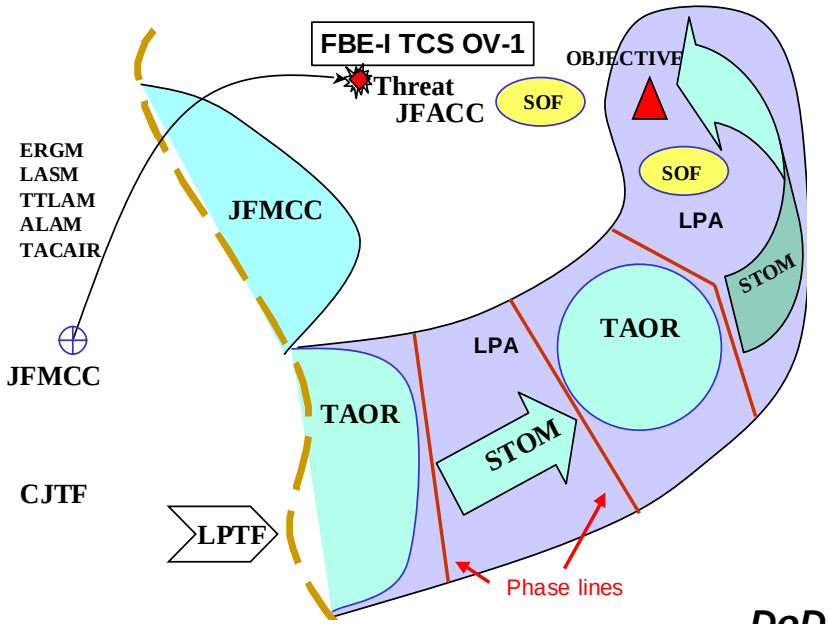
Operational Concept in an Integrated Architecture

Fleet Battle Experiment – India (FBE-I)



- **Enterprise level Operational Concept for the mission should**
  - **Integrate OV-4 and OV-5 in context**
  - **Highlight details of special interest**
- **Scenario events can be related to operational activities.**
- **This allows the OV-1 to be regarded as part of the data repository for the *Integrated Architecture.***

DoDAF Nomenclature

OV-1: High Level Operational Concept Graphic
OV-4: Organizational Relationships Chart
OV-5: Operational Activity Model

Frederick P. Brooks, The Mythical Man-Month, 1974 and 1995:
"… the critical need [is] the preservation of the conceptual integrity of the product."

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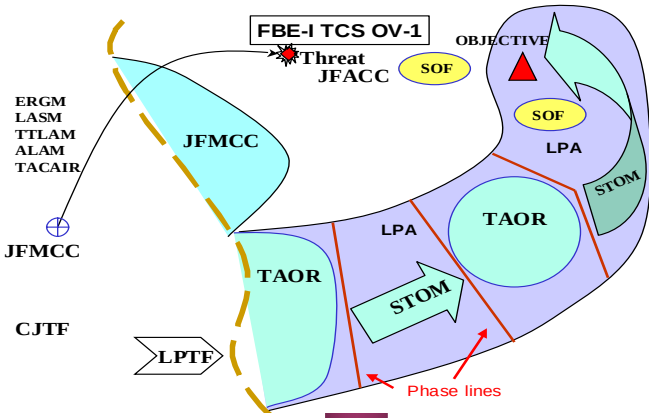
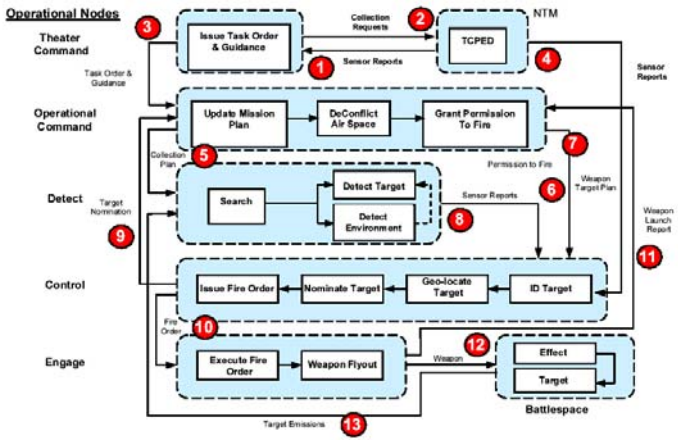
Realizing Operational Capabilities

Concept

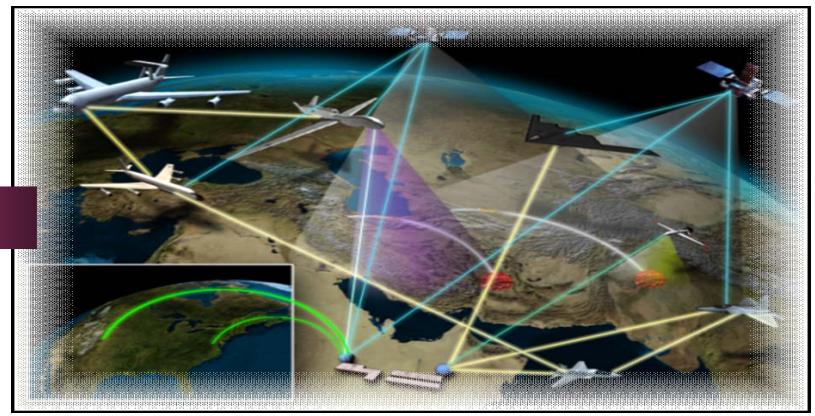


Scenario

Capability



System & Network Architecture



An integrated architecture using a capability model as the reference model can provide the basis for operations analysis.

Architecture-based Operations Analysis

Proposed Definition

Architecture-based operations analysis **relates to an analysis of operations that can be used to demonstrate changes in operational capabilities that are attributable to changes in the integrated architecture, e.g. changes in:**

Structure	**Relations**
Rules	**Governance**

Examples include: the creation or elimination of nodes, the interoperability between nodes, changes in technical standards, changes in C2, etc.

Architecture-based operations analysis **should support the systems engineering of a Family of Systems (FoS)* to achieve specified capabilities through the individual operation and collective interoperation of the systems in the FoS.**

****Using Architectures for Research, Development, and Acquisition, C.E. Dickerson, et al***

West-Central Sudan Scenario

Fleeting and Deceptive Target

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Sudan

- **Theater assets tasked to locate WMD targets suspected to be operating in west-central Sudan**
- **Expeditionary Strike Group, JSOTF embarked in Red Sea**
- **Surveillance assets tasked with wide area observation**
  Sensor Capability: Global Hawk, Predator, MIUGS
- **Objective: hold a fleeting and deceptive WMD target at risk**

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West-Central Sudan Order of Battle

Red OOB

Threat Vehicles

Thirteen Vehicles Assumed in OpArea

- Two Scud TELs
- One SA-6 SAM
- Three supply trucks
- Two ZSU-23-4 Anti-Aircraft systems
- Three civilian trucks
- Two military support vehicles

Blue OOB

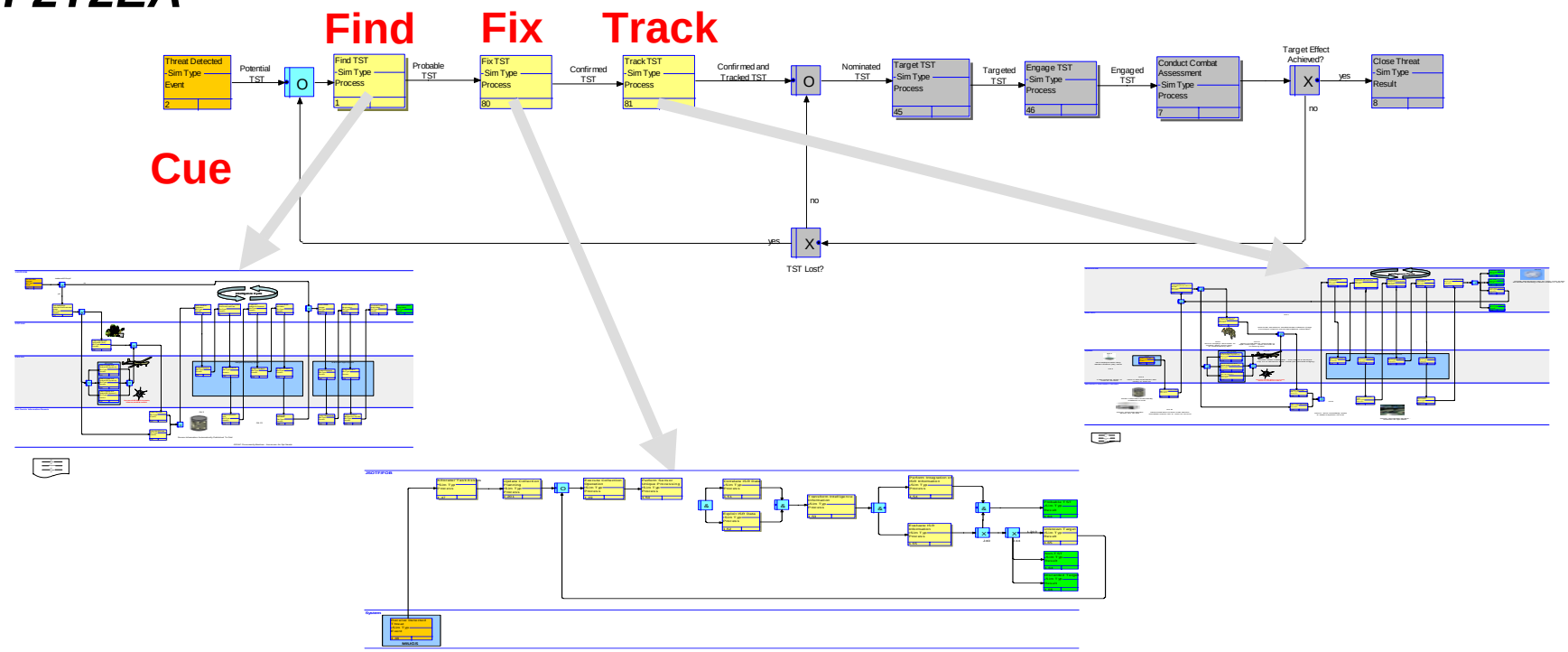
Theater Sensors

	MIUGS	Predator B	Global Hawk*
Altitude (km)	0	13	20
Sensor Range (km)	3	5	100*
Probability of Detection	1.0 @ 500m 0.65 @ 3000m	1.0 with zoomed FOV	0.9 @ 100km
Range Accuracy (m)	100	10	10
Azimuth Accuracy	100m	10m	3 mrad
Speed (m/s)	Emplaced	Enroute 60 Loiter 35	175

* MTI only

Capability Model

F2T2EA



Key Performance Parameter: ***Track Time (Location with ID)***

Primary KPP: ***Time in Continuous Track***

Maximum track length (i.e. continuous) > 30 minutes

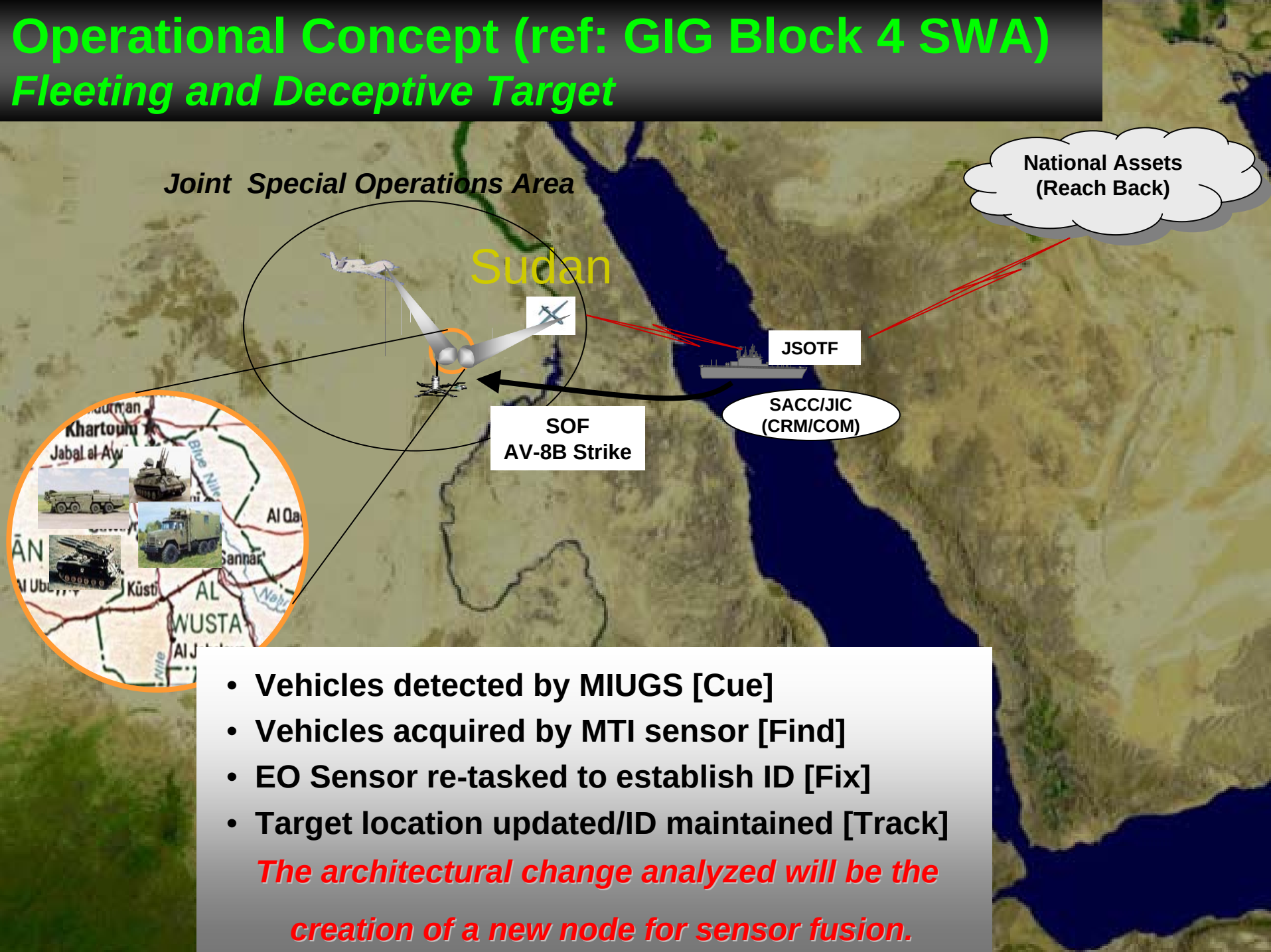
Classification ID Confidence > 0.9

Secondary KPP: ***Total Time in Track (i.e. with interruptions)***

Requirement depends on weapons, scenario events, …

Operational Concept (ref: GIG Block 4 SWA)

Fleeting and Deceptive Target



- Vehicles detected by MIUGS [Cue]
- Vehicles acquired by MTI sensor [Find]
- EO Sensor re-tasked to establish ID [Fix]
- Target location updated/ID maintained [Track]

The architectural change analyzed will be the creation of a new node for sensor fusion.

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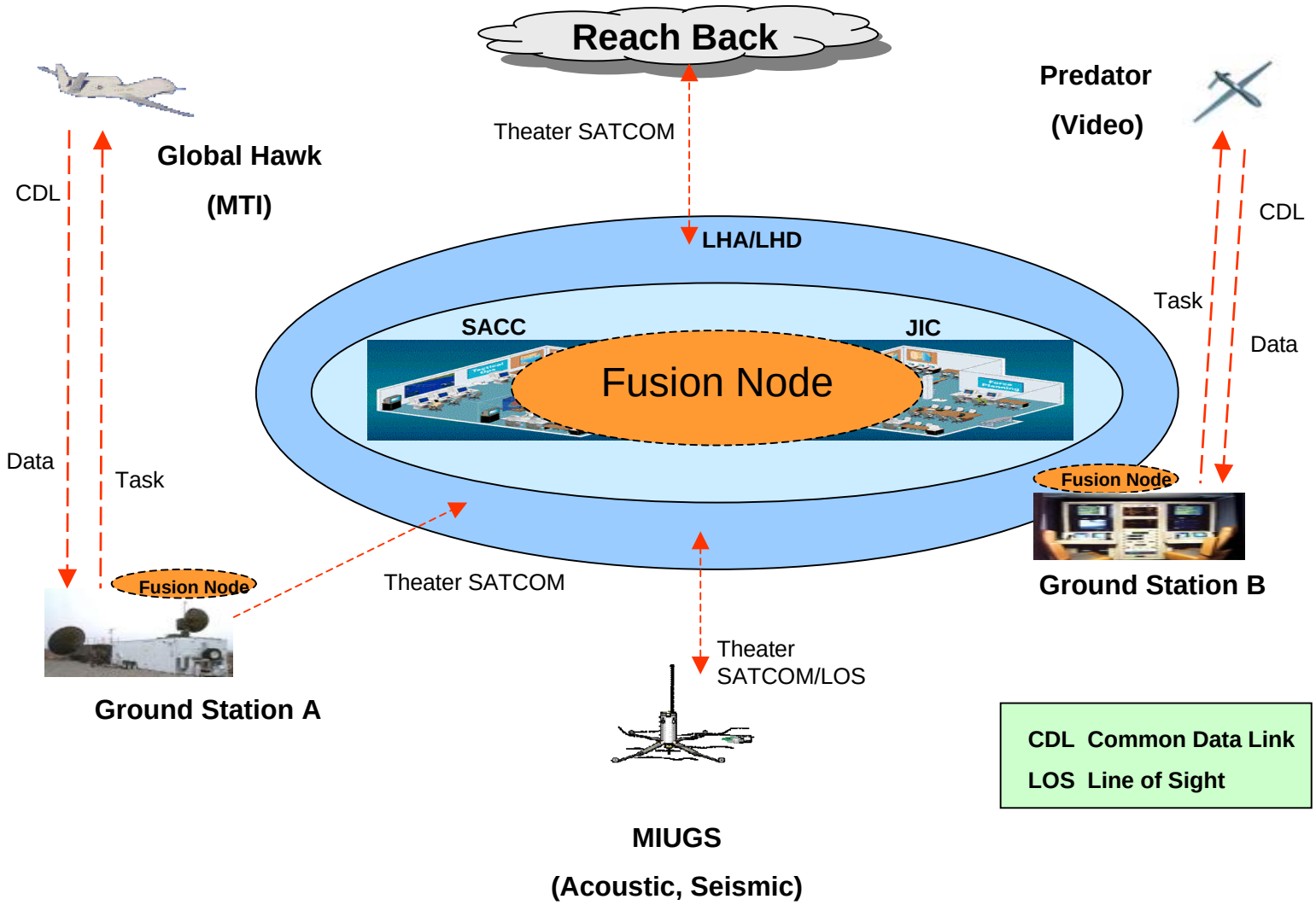
Sensor Fusion Node Description

External View of the Node (Relation to the C3ISR Architecture)



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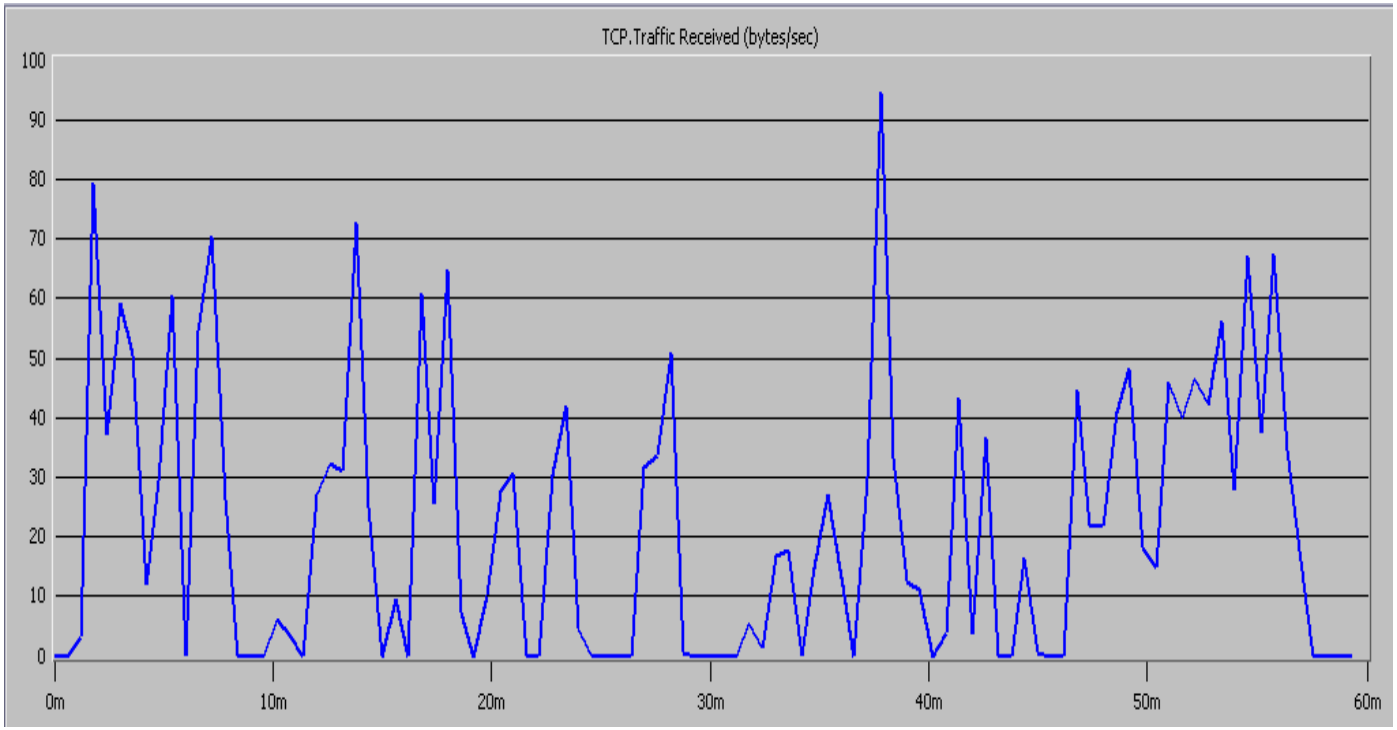
C3ISR Architecture Supports Sensor Fusion

Increased Track throughput peaks at only 20-30% of one channel*

MIUGS-Global Hawk-Predator (736bps peak)

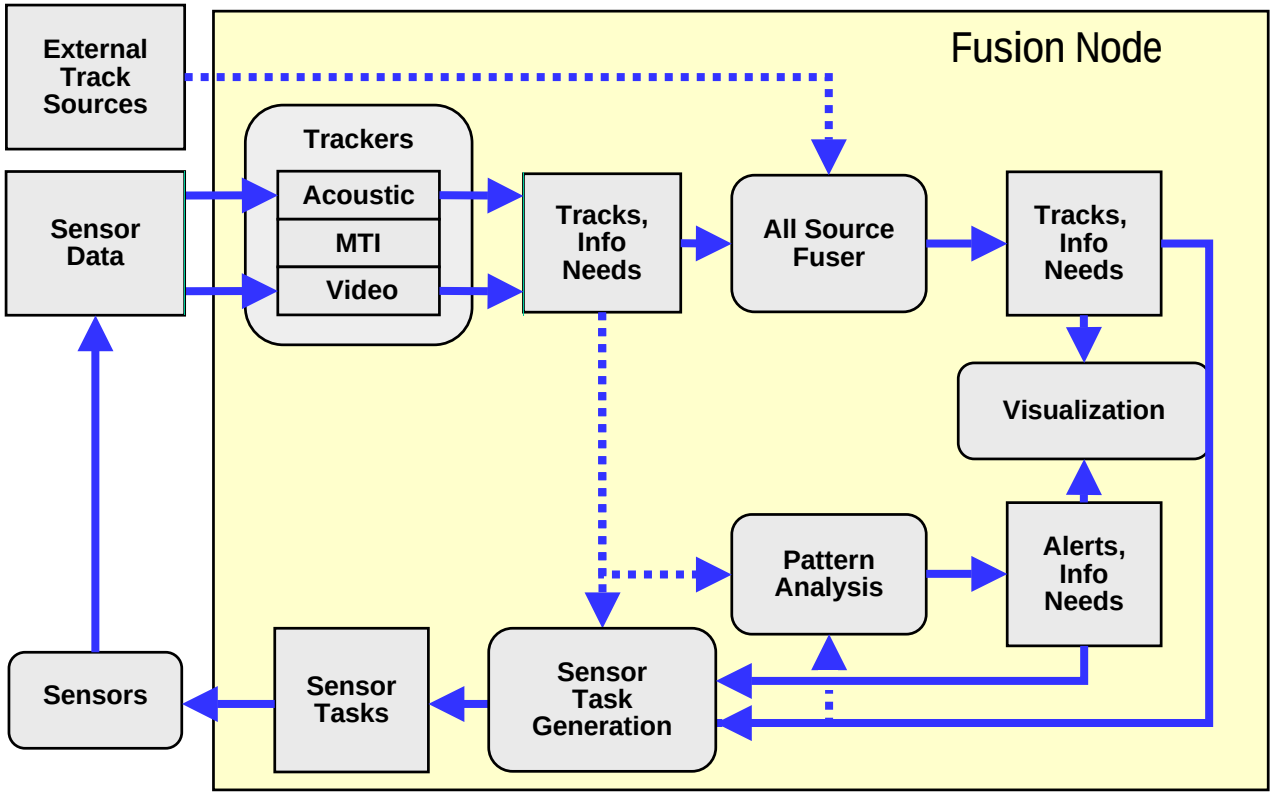


OPNET modeling provides communications loading estimates and preliminary validation of interoperability

*** UHF SATCOM was the lowest throughput node in the C3ISR architecture (providing 16-20 2.4 kbps channels).**

Sensor Fusion Node Description

Internal View of the Node



	Cue	ID	Track
Acoustic	+	-	+/-
MTI	+	-	+/-
Video	-	+	+

BAE-AIT Fusion Performance Model Predicts Fusion Node Performance

Global Hawk, MIUGS & Predator Scenario

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Primary roads

Secondary roads

TEL Launch Site

TEL Hide Site

TEL Reload Site


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Emplaced MIUGS field
MIUGS Acoustic/Seismic detection ranges
500m, Pd = 1.0
3000m, Pd = 0.65
TEL Hide Site

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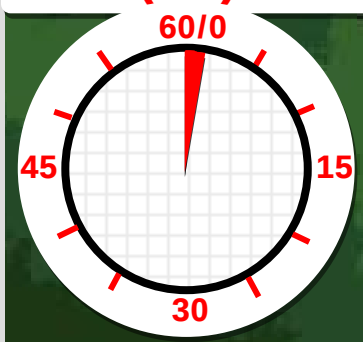
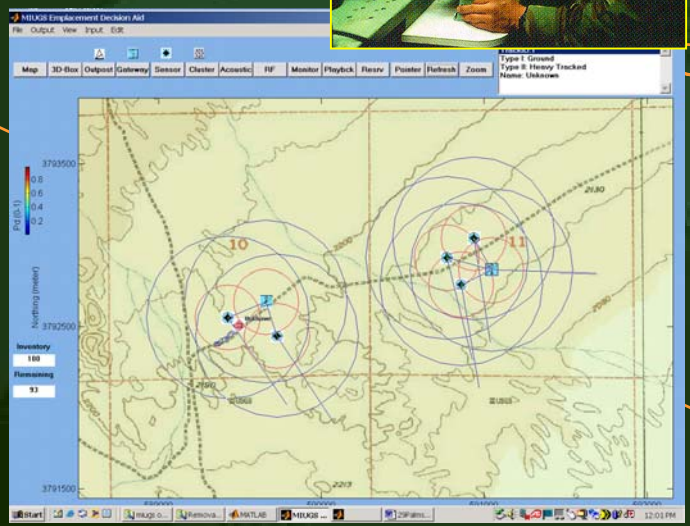
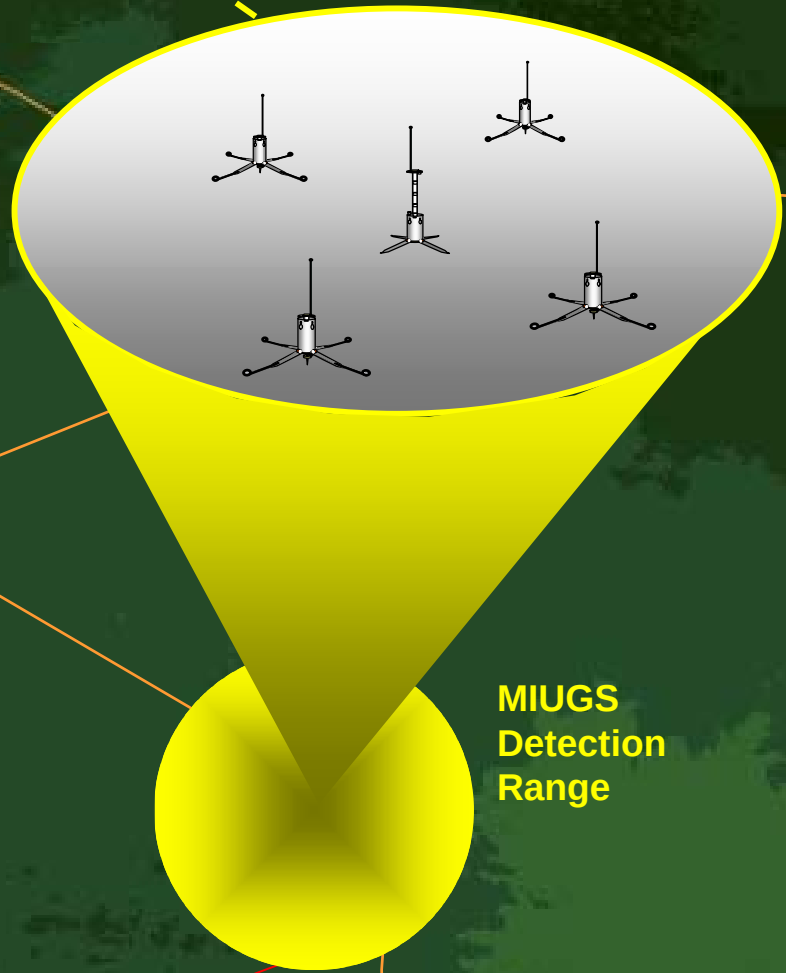
Mission Time (min)







MIUGS Detection Range

TEL Engine Start

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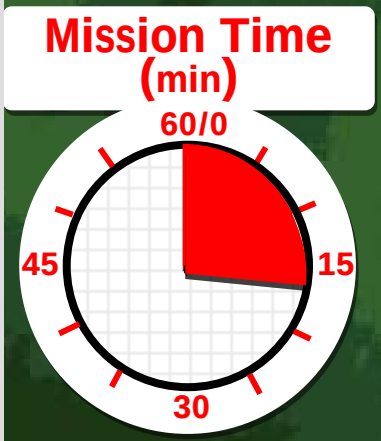

TELs out of MIUGS Detection Range

Elapsed Time: 966 sec

Periodic MIUGS updates

(30 sec intervals)

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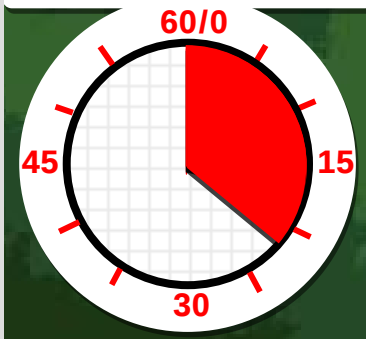
Mission Time (min)



Predator B

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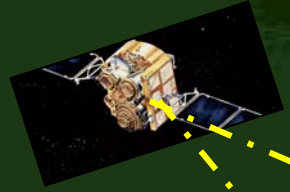
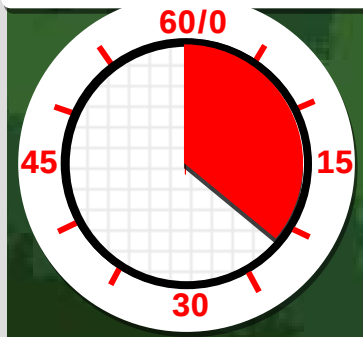


Mission Time (min)



Predator locates TELs and reports

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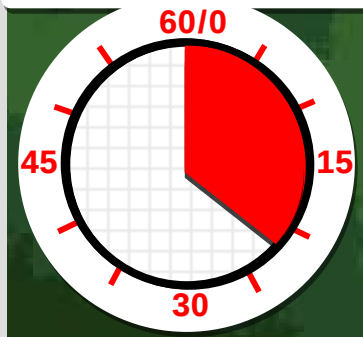
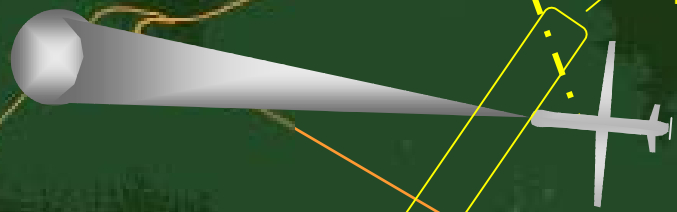
Mission Time (min)



Predator Video
Elapsed Time: 1380 sec

Predator orbit commanded from Ship



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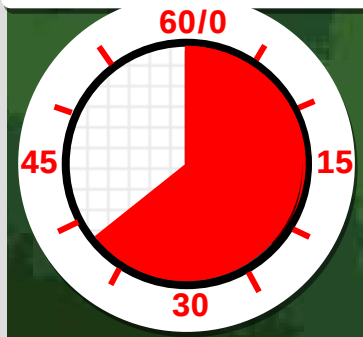
Mission Time (min)



Global Hawk re-establishes track

TELs move to launch site

Elapsed Time: 1980 sec

Predator Video

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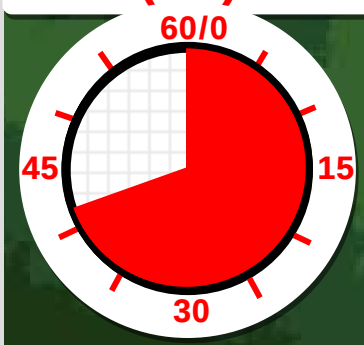
Mission Time (min)



Global Hawk and Predator maintain track
Elapsed Time: 2440 sec

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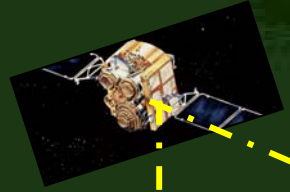
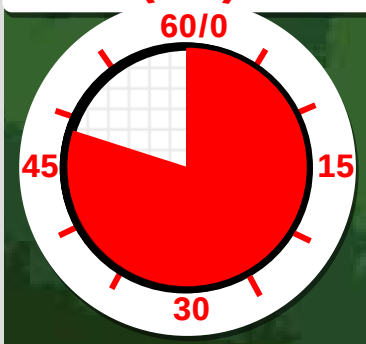


Mission Time (min)



TELs at launch site
Elapsed Time: 2900 sec

Predator Video

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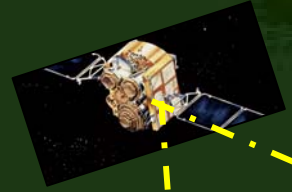
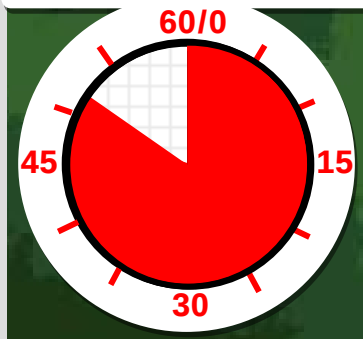
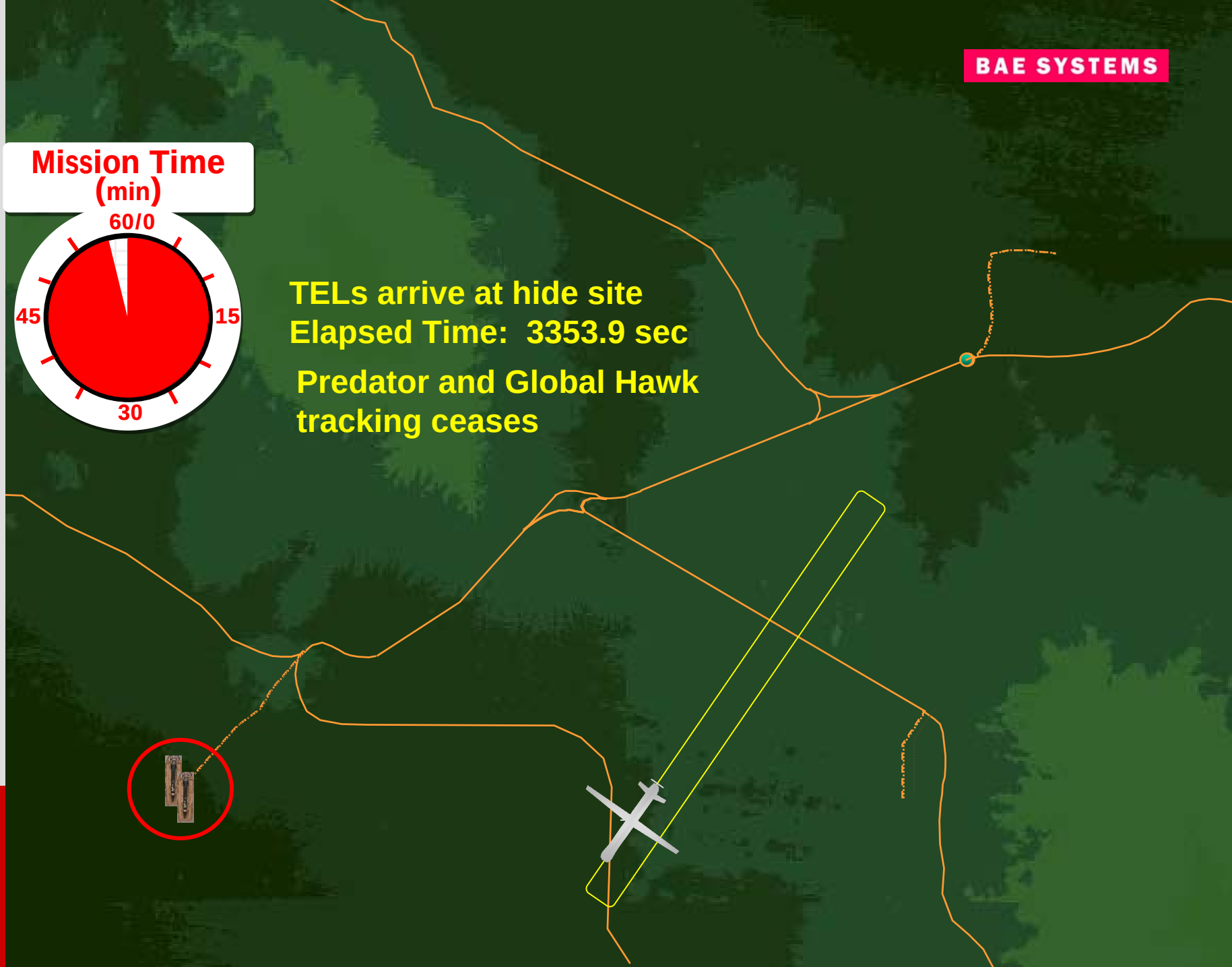


Mission Time (min)



TELs depart launch site
Elapsed Time: 3120 sec

Predator Video



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Measures of Performance*

* Statistical average of two TELs

	MIUGS Only	Global Hawk Only	MIUGS & Global Hawk	Global Hawk & Predator	MIUGS, Global Hawk & Predator
Time to Find (min)	0.7	5.3	0.5	5.3	0.7
Time to Fix (min)	1.0	5.6	0.8	5.7	0.9
Total Time in Track (min)	15.9	35.1	42.2	44.3	50.2
Maximum Track length	9.2	9.2	9.4	16.5	15.5
Track Length following ID	-	-	-	16.5	15.3
Time of first ID Declaration	-	-	-	22.7	20.4
ID Confidence	-	-	-	0.99	0.96
Tracking Accuracy (m)	56.0	8.3	8.3	6.4	6.4

Key Performance Parameters (KPPs):

Primary – Maximum Track Length
– Classification ID Confidence
Secondary – Total Time in Track

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Conclusions

- For the sensors and GIG scenario analyzed,
  - Fusion allowed the sensor architecture to support the operational objective for the secondary KPP (i.e. to hold a fleeting and deceptive target at risk with interrupted track)
  - The operational objective was not met for the primary KPP
  - Aggregation of the minimal functionality needed was achieved by creating a new systems node for sensor fusion
  - The new node was supportable within the existing C3ISR architecture
- An Integrated Architecture can provide the basis
  - For the analysis of operations and capabilities
  - To attribute changes in operational capabilities that are caused by changes in the architecture

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Architecture-based Operations Analysis

You have now seen the tip of the iceberg …

In a new area of operations analysis!


BACKUP

Find, Fix and Track (F2T) Phase Duration for High Value Targets

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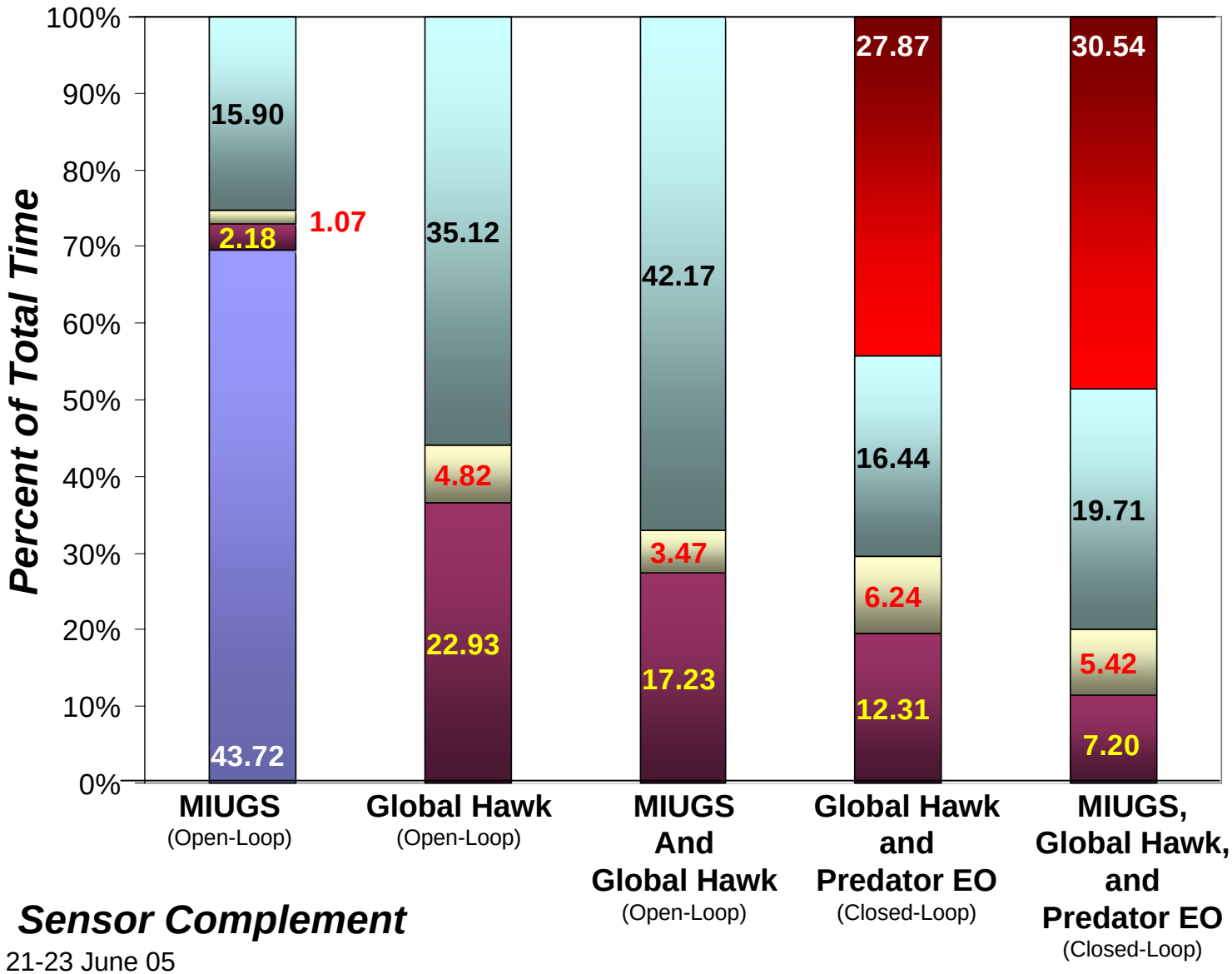

Sensor Complement

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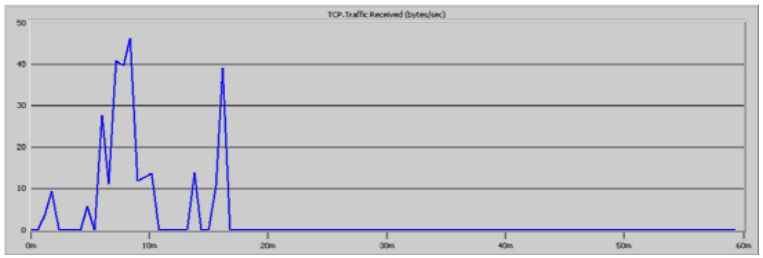
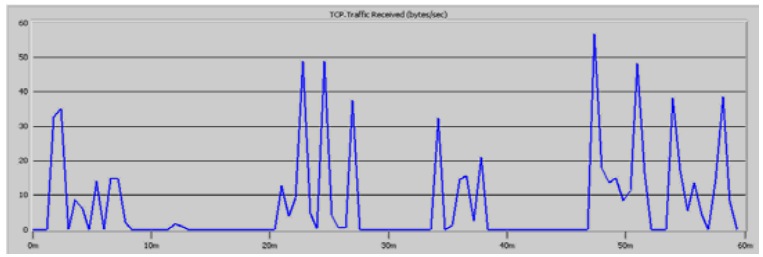
UHF SATCOM link usage (16-20 2.4kbps channels)

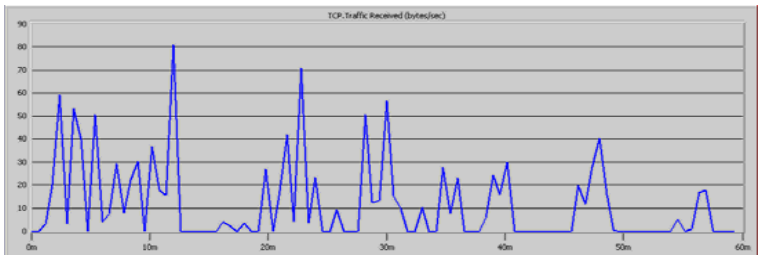
MIUGS Only (376bps peak)



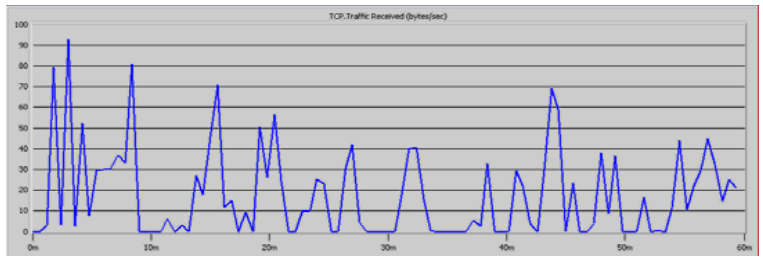
Global Hawk Only (456bps peak)



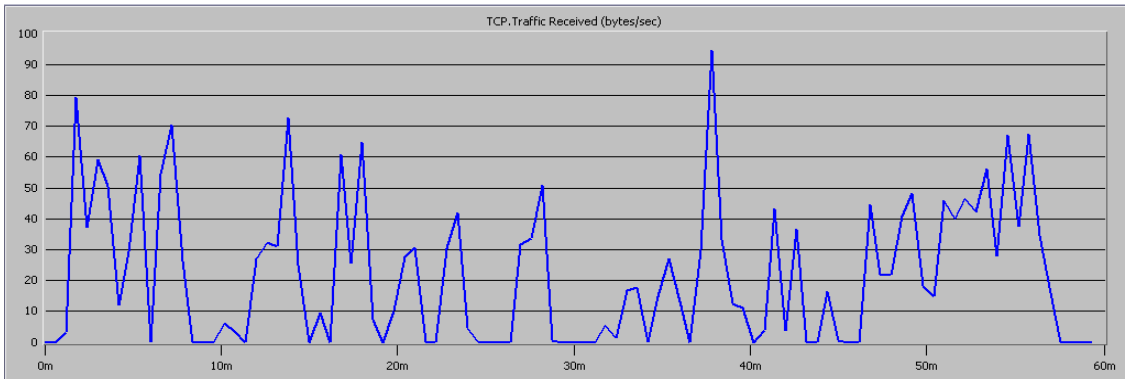
Predator-GH (640bps peak)



MIUGS-GH (736bps peak)



MIUGS-GH-Predator (736bps peak)



Fusion Related Definitions

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- Open-Loop
  - Open loop tasking involves a sensor constellation performing its collection plan as predetermined during the planning phase of the mission.
- Closed-Loop
  - Closed loop tasking involves changing a sensor constellation's collection plan in near real time to focus collection assets on objects of interest as they are discovered by the constellation.

Fusion Related Acronyms

BAE SYSTEMS

- BAE-AIT
  - BAE Advanced Information Technologies, Burlington, MA, USA
- ATIF
  - BAE AIT All-source Track and ID Fuser
- FPM
  - BAE AIT Fusion Performance Model

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